FINITE ELEMENT SIMULATION OF BLANKING PROCESS

AFZAL AHMED[1] AND HASMIRA MUHAMAD[2]

[1]*COMSATS Institute of Information Technology, Sahiwal, Pakistan.*

[2]*School of Mechanical Engineering, Universiti Saians Malaysia, Penang, Malaysia.*

ahmed_462001@yahoo.com

ABSTRACT: The blanking process can be simulated by ABAQUS v 6.4 to select punch, die and press and ascertain punch wear and bur height. The experimental and the simulation results agree well with rising punch force up to the point of creation of crack. For a 2mm mild steel sheet, the simulation shows that for the punch force of 240 kN, the crack starts at 30% punch penetration depth and punch force suddenly drops to a value of 70 kN and remains steady till the blanking is complete. Comparing simulation and experimental results for a 3mm mild steel sheet, results agree well in the elastic range with the punch force rising up to point of crack creation. However, a discrepancy appears in punch force which increases with punch penetration. At 32% depth of penetration, the discrepancy is 12 % which increases to 60 % at punch penetration of 42%. Punch force for experimental and simulation results remains about 90kN beyond punch penetration of 62%. Also, increase of the thickness of sheet results in reduced crack height and improved quality of blank.

ABSTRAK: Proses pengosongan boleh disimulasikan oleh ABAQUS versi 6.4 untuk memilih tebuk, alat dan tekan; dan menentukan haus tebuk dan ketinggian duri. Keputusan ujikaji dan simulasi adalah serupa dengan kenaikan daya tebuk hingga titik retakan diperolehi. Bagi kepingan keluli ringan 2mm simulasi menunjukkan bahawa untuk tenaga tebukan sebanyak 240 kN, retak bermula pada 30% kedalaman penembusan 30% tebukan dan daya tebuk tiba-tiba jatuh kepada 70 kN dan jumplah ini kekal sehingga proses pengosongan selesai. Apabila hasil simulasi dan eksperimen dibandingkan, keputusan experimen untuk keluli lembut 3mm, bersetuju dengan baik dalam julat anjal dan daya tebukan meningkat sehingga titik penciptaan retak diperolehi. Walau bagaimanapun percanggahan muncul apabila daya tebukan meningkat dengan daya penembusan. Pada kedalaman penembusan 32% percanggahan adalah 12% dan nilai ini meningkat kepada 60% apabila daya penembusan sebanyak 42%. Daya tebukan yang diukur melalui eksperimen dan simulasi kekal pada kira-kira 90kN melepasi penembusan punch sebanyak 62%. Apabila ketebalan keputusan kunci ditambah, ketinggian retak dikurangkan dan ini meningkatkan kualiti pengosongan.

KEYWORDS: *simulation; finite element simulation; blanking; computer aided manufacturing*

1. INTRODUCTION

In a blanking process, metal is cut by using a punch and die on mechanical or hydraulic press. The quality of sheared edge depends not only on the material but also the process parameters such as the clearance between the punch and the die, the blank holding force, and the sharpness of the edge of punch and die. Klingenberg and Singh [1] describe the blanking process in five stages; Stage I: As punch pushes into the sheet held by the blank holder, the sheet is elastically deformed. Stage II: As the punch continues to push, first outer fibers of sheet then all inner fibers of sheet between punch and die are subjected to yield strength. Stage III: The fibers of sheet between punch and die become thin and undergo plastic deformation and a crack starts developing. Stage IV: A full crack develops and the force which pushes the punch is reduced. Stage V: Finally the punch pushes the slug through the die hole.

With the advent of computer, the blanking process can be simulated and this can reduce time and cost in engineering decision making and equipment selection. In computer propagation of crack is simulated by mechanical fracture models. Three methods are used to realize a fracture in FE-Mesh, that is, element splitting, element separation and element deletion. A number of damage models (Mclintock [2] Cockroft/Latham, [3]; Rice and Tracey, [4]; Gurson [5]; Lemaitre, [6]; Husson et al. [7], Tvergaard [8] have been developed to try to simulate the development and propagation of ductile fracture. The aim of paper is to apply FEM along with crack damage model to simulate the blanking process and compare with experimental results. The computer program to simulate the blanking process is ABAQUS/CAE v 6.4 [9]. This is finite element program designed to model the behavior of solids and structures under externally applied loading. The simulations were considered for blanks of mild steel sheets of different thicknesses. The results of simulated blanking process are compared with experimental results.

2. SIMULATION OF BLANKING PROCESS

In this paper Lemaitre model is used for crack initiation and propagation[6]. In Lemaitre model the isotropic damage variable is the ratio between the total area of the micro cracks and cavities and cross sectional area of the material.

2.1 Model Geometry

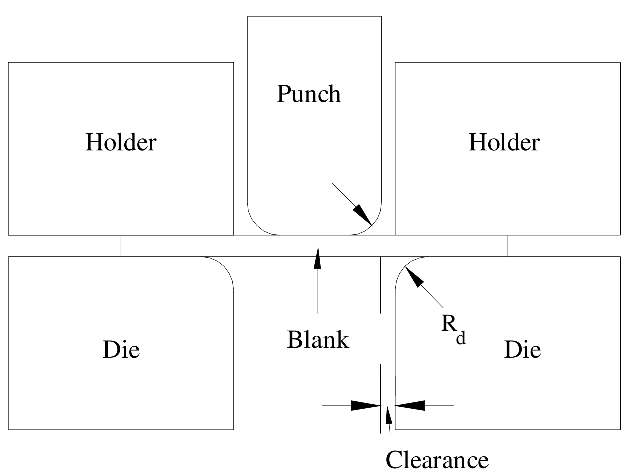

Fig. 1: Geometry of punch, die, blank holder, sheet and clearance.

Figure 1 shows the schematic diagram of the blanking process components which are punch, die, blank and the blank holder. The punch diameter is 30 mm. The punch-die clearance is 1 % of the blank thickness. The blanks are of mild steel sheet of 2 mm, 3 mm and 4 mm thickness. The tool wear is simulated by rounding off the cutting edge of the punch and die. The punch had edge radii of 0.01 mm, 0.06 mm, 0.12 mm, 0.2 mm, whereas die and blank holder edge radii were of 0.01 mm. Following assumptions are made in the analysis:

1. The process is simplified to a two-dimensional situation, under plane-strain conditions.
2. The process is considered quasi-static, and hence the effects of strain rate are neglected.
3. The sheet material is considered as elastoplastic while the punch and die are defined as rigid.
4. The friction between sheet and tool follows Coulomb's law.

2.2 Input Data for Modeling

The blanking of mild steel sheets as blank of thickness of 2 mm, 3 mm and 4 mm was simulated with punches with different edge radii R_p = 0.01 mm, 0.06 mm, 0.12 mm and 0.2 mm; the blank holder and the die with edge radius R_d=0.01 mm.that contacts the blank.

The tools are modeled as hard surfaces with Rockwell hardness of C60-62 and modulus of elasticity of 210 GPa. because they are stiffer than the blank A two-dimensional plain strain model is used. Only half of the blanking is modeled because the blanking process is symmetric about a plane along the center of the blank. The blank is of mild steel having Modulus of elasticity, E= 207.0×10^9 Pa, and Poisson's ratio = 0.29. The material undergoes considerable work hardening as it deforms plastically.

2.3 Part Definition

For ABAQUS/CAE part module four parts are created. They are: one deformable part named the blank and other three are rigid parts named punch, holder and the die. The edge radius of the punch, R_p is created with required values. A rigid body reference point need to be created. The point at the centre of the arc in view port is selected as the rigid body reference point. In the property module, a material named mild steel 2 mm is created. A homogeneous solid section named BlankSection is also created that refers to material steel.

2.4 Mesh Creation

In the Mesh module , the blank is meshed using CPE4R elements, that is, four node element with thickness in plane strain . It is two dimensional consideration. Forty elements along the horizontal edges of the blank and sixteen elements along each region on the vertical edges of the blank are specified. The total numbers of nodes were 1143 and elements1006. Figure 2 shows the mesh in shear zone.

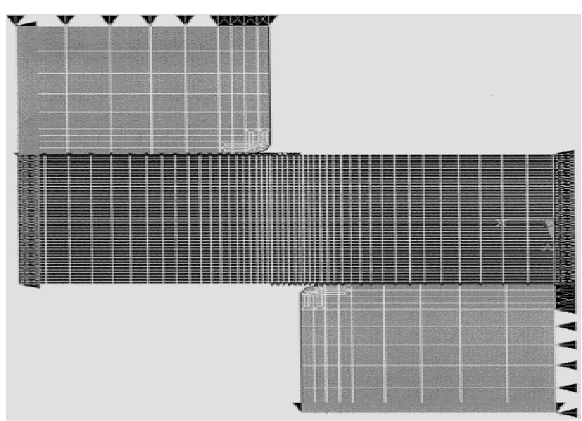

Fig. 2: Mesh in the shearing zone.

The blanking process is carried out as per the procedure described by ABACUS /CAE. Figures 3 and 4 show the shape of 2 mm MS sheet before and after the application of punch force.

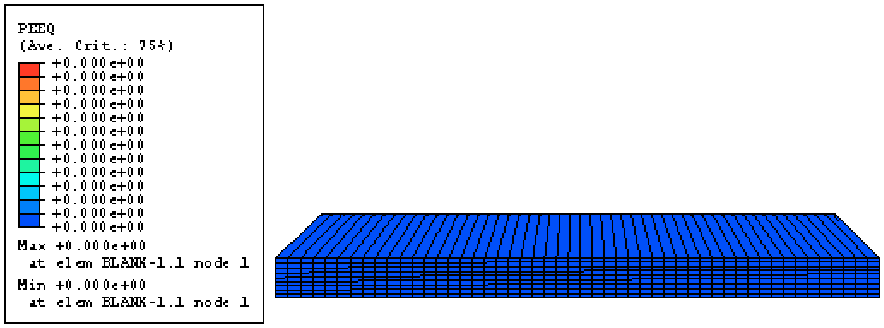

Fig. 3: Contour of undeformed shape in blanking process of mild steel 2 mm.

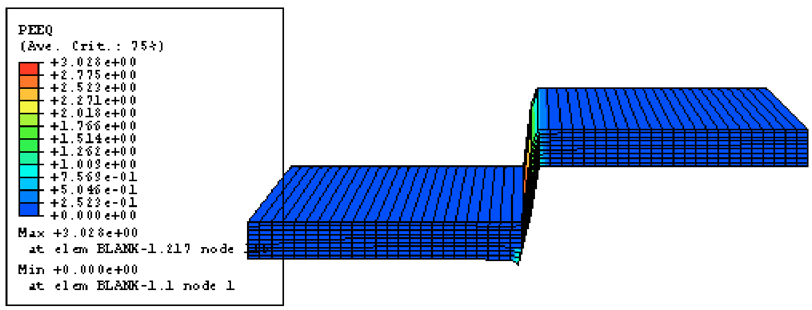

Fig. 4: Contour of shape after blanking process of mild steel 2 mm.

3. RESULTS AND DISCUSSION

Figure 5 shows the simulation of punch force vs punch penetration for a 2 mm thick mild steel. The force rises initially up to about 240 kN with elastic and plastic yielding. A crack develops and force drops to 70 kN. The crack propagates now at a constant force.

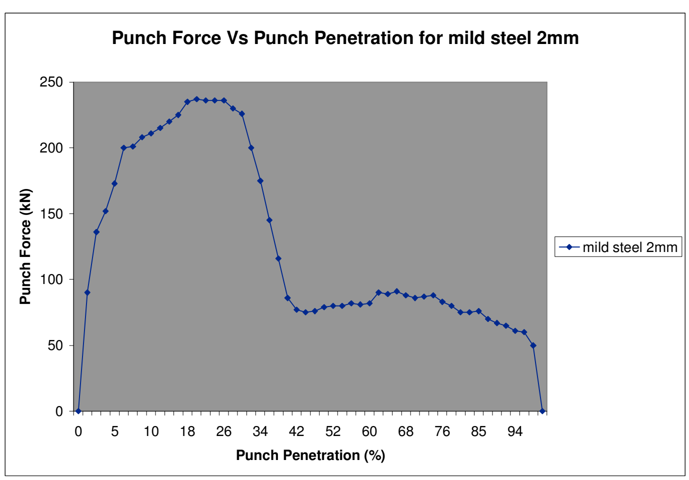

Fig. 5: Punch force vs punch penetration of blanking process (2 mm MS sheet).

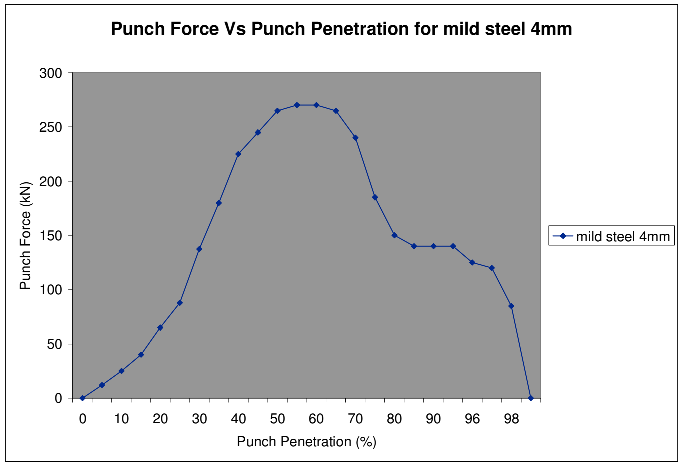

Fig. 6: Punch force vs punch penetration of blanking process (4 mm MS sheet).

Figure 6 shows the simulation of force vs punch penetration for mild steel sheet of 4 mm thickness. The curve is slightly different from that of 2 mm mild steel sheet because of the effect of increased thickness of sheet. There seems to be a resistance in the initiation of crack as the crack starts at about 70% punch penetration. Further the peak force lowers from 270 kN to about 140 kN with penetration up to 80%. Unlike 2 mm sheet the crack does not propagate at a nearly constant force but propagates with the reduction of force. Further the fracture height is less, that is, fracture height reduces as the sheet thickens. Hernandaz et al. [10] studied the effect of clearance between die and punch ranging from 5% to 8% and found that the depth of start of crack increased with smaller clearance, however, decreased when clearance is increased. In the present study for a very small clearance of 1%, high values of punch penetration till the completion of blanking conforms to results of Hernandaz et al. [10]. Since $R_d/R_p < 0.7$, the crack will initiate from the die corner according to Farzin et al. [11].

Figure 7 shows the comparison of simulation results with that of the experiment. The experimental results are taken from the research paper by Hambli and Potiron [12]. The experimental and simulation results are for 3 mm mild steel sheet with punch edge radius of 0.01 mm. The figure shows good agreement in experimental and simulation results in elastic and plastic range but the development of crack starts at varying depth of punch penetration. In simulation the crack starts at about 30% penetration wheras in actual crack starts at about 34% penetration. However, the final force in simulation required for separation of blank from sheet tallies with that of experiments.

Figure 8 shows the experimental results by Hambli and Potiron [12] for punch force vs punch penetration for 3 mm thick mild sheet for different punch edge radii. The increase in punch edge radius exhibits the wear of the punch.

Figure 9 shows the simulation results for the similar experimental data of Fig. 8. The punch force in elastic plastic region are in close agreement with those from experiment that is all reach 250 kN and also have same start of crack at punch penetration of 30% depth. However, the final force requirement for separation of blank from sheet is different in case of experimental results- a lower force of 50 kN for the worn punch of edge radius of 0.2 mm. This seems to be because of different worn radius of the punch. In case of simulation the force of separation of blank from sheet is nearly same for tool and worn tool again because of the limitation of damage model. However, by simulation one can estimate the punch force requirement to determine the capacity of press needed. Also the effect of punch wear on fracture height and bur height can be determined which in turn signify the quality of the blank.

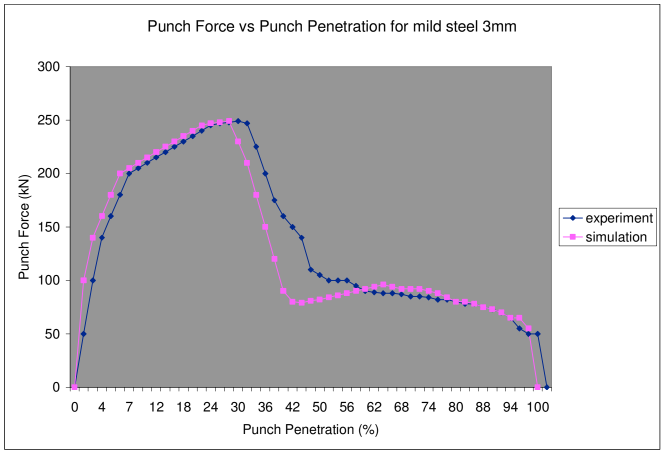

Fig. 7: Simulation compared with experimental results of Hambli and Potiron [12].

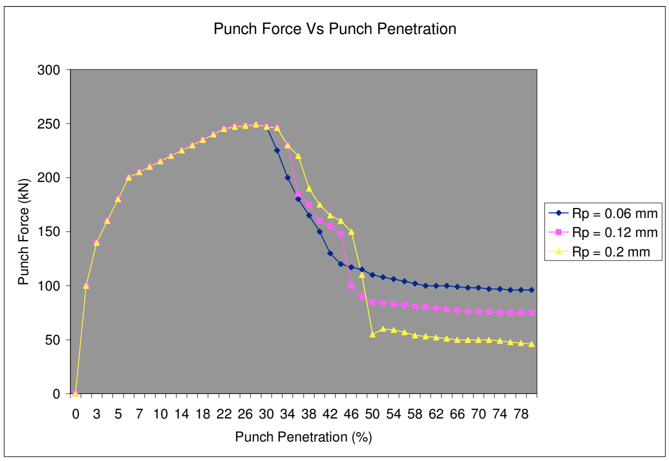

Fig. 8: Experimental results for punch force vs punch penetration of 3 mm MS Sheet for various punch edge radii reported by Hambli and Potiron [12].

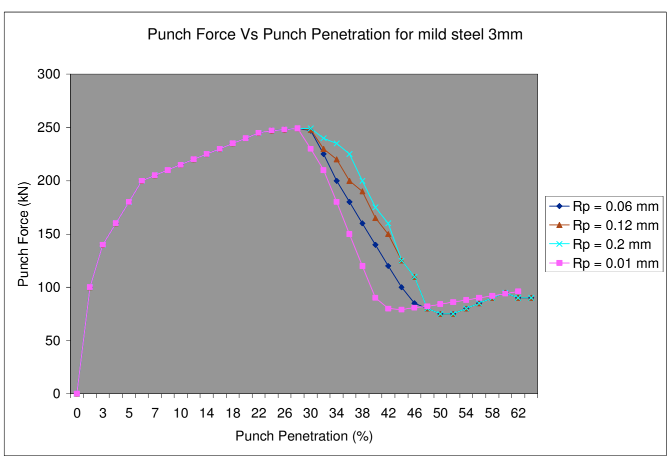

Fig. 9: Simulation of punch force against punch penetration for various punch edge radius for blanking of 3 mm MS sheet.

4. CONCLUSION

The ABAQUS v 6.4 satisfactorily simulates the blanking process. The elastic plastic range simulation is well in agreement with experimental results. After plastic deformation a crack develops and the FEM model incorporating Lemaitre damage model [6] approximates well the crack propagation. As the crack develops the punch force is reduced considerably and punch penetrates depending on the punch edge radius. With increased thickness of sheet the crack height is reduced and the blank quality is improved. The changing punch wear(edge radii) does not change the force markedly in elastic region. However, in the plastic/fracture zone the different punch wears complete the blanking at different forces as observed in experiments by Hambli and Potiron [12]. This marked difference is not much obvious in simulation because of the use of damage model which does not take into account the punch wear.

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